Paper Proposal for *Integrating Technology TIG:*

**Three Keys to Fusing STEAM Education:**

**Digital Multimedia, Design Tools, and Computer-based Adaptive Evaluation**

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*Overview*

The primary goal of this discussion is to encourage teacher change towards an interdisciplinary pedagogical approach, wherein content areas are not competing with one another for time in the classroom, but rather they enhance each other in tandem -- with overlaps and connections celebrated and emphasized rather than trivialized or ignored. While the substantial resources necessary for supporting such an interdisciplinary pedagogy were once difficult to obtain, recent innovations in technology and multimedia have made this profoundly impactful style of education accessible to any teacher willing to invest the time in becoming proficient in more than one academic discipline and application of the proposed interdisciplinary instructional model. More specifically, the convergence of these three specific educational technologies now makes high-quality interdisciplinary pedagogy realizable and scalable: digital multimedia (DM), design tools (DT), and computer-based adaptive evaluation (AE). Digital multimedia is necessary for scalable interdisciplinary education because it provides repeatable experiences with difficult to access persons such as an historical figure like Dr. Martin Luther King, Jr., or events like an erupting volcano. Design tools such as rapid-prototyping hardware and software technologies enable students to transition from abstractly interacting with STEAM content (Science, Technology, Engineering, Arts, and Mathematics) to physically creating products that transform ambiguous concepts into concrete experiences. Computer-based adaptive evaluations are assessments that enable students to move at their own pace and that also relieve teachers from feeling overwhelmed with grading additional student work. These three educational technologies can work cohesively to integrate STEAM together into a potent pedagogical solution for many of our contemporary educational ailments including low student achievement and lack of engagement.

*Problem Addressed*

This discussion will be organized by separate definitions and discussions of each of these three strands, and then a synthesis of the strands into a coherent framework that provides a foundation for interdisciplinary STEAM pedagogy. Evidence has consistently indicated that traditional mathematics curriculum and instructional methods are not serving students well with too few students graduating from high school prepared to begin an accredited undergraduate STEM degree program (Diaz & King, 2007; Hiebert, 1999), a necessary minimum prerequisite for almost all high-paying STEM-related careers. Instead, these high school graduates face common recognized barriers that impede engagement and motivation in mathematics education, particularly learning anxiety, as the negative relationship between mathematics anxiety and achievement and career choices has been well documented (Ho et al., 2000; Lee, 1992; Satake & Amato, 1995). One possible cause for this anxiety is that many abstract mathematics concepts are difficult for students to connect with their life experiences, which results in limited understanding (Sweller, 1999). Consequently, students’ motivation and engagement can be reduced, and their attitude and confidence may be damaged, which in turn impedes their learning of mathematics. The proposed interdisciplinary instructional model incorporates activities into classrooms that contextualize application of mathematical skills into real-world problem solving challenges (Bursal et al., 2006) in order to reduce students’ mathematics anxiety and cultivate a positive attitude toward mathematics.

*Solution Presented: Theoretical Framework and Previous Research*

Contextualized interdisciplinary mathematics education can provide opportunities for students to make sense of and apply mathematics knowledge in meaningful ways as they connect new knowledge to existing knowledge (Schoenfeld, 1988). Recent studies have suggested that integrated STEAM teaching strategies benefit students in a number of ways related to mathematics outcomes, including: (1) improved motivation to learn mathematics (Glastra, Hake, & Schedler, 2004), (2) enhanced engagement in self-reflection and active inquiry (Parson, 2005); and (3) a more enjoyable and collaborative learning environment (Robertson & Lesser, 2013). The natural connections between mathematics and the arts offer teachers a rich educational resource to develop mathematics lessons based on meaningful connections with creative activities and foster motivation and engagement in mathematics. Activities such as musical instrument design have been used to teach different mathematics topics (An, Capraro, & Tillman, 2013), and results from these studies showed that mathematics pedagogy contextualized within art-themed activities can serve as a mechanism for improving K-12 students’ mathematics achievement and attitudes (An, Ma, & Capraro, 2011; Carrier et al., 2011; Colwell, 2008; Costa-Giomi, 2004; Johnson & Edelson, 2003; Lesser, 2001). Important mathematics concepts such as patterns, structures, symbols, algebraic and geometric relationships can all be explored in both the arts and mathematics (Fauvel, Flood, & Wilson, 2006; Loy, 2006), and an integrated STEAM teaching approach has been shown to enable students to easily transfer knowledge between arts to non-arts subjects as they build the connections between empirical artistic experiences and abstract mathematical concepts (Catterall, 2005). Furthermore, art-themed activities have been shown to provide students with an emotionally stimulating mathematical learning context, and this in turn can reduce their mathematics anxiety (Eisner, 2002; Sylwester, 1995; Upitis & Smithrim, 2005). By contextualizing mathematics education into art-themed activities, the natural overlap offers educators additional resources for teaching students to explore, understand, analyze, and interpret mathematics (An, Ma, & Capraro, 2011), while at the same time fostering engagement and motivation in this often anxiety producing subject (An, Capraro, & Tillman, 2013).

*Solution Presented: Scalability of Instructional Model and Assessment*

The primary goal of interdisciplinary STEAM education is to help students improve their academic achievement and dispositions by learning via analysis, synthesis, and creativity. Within this instructional model, students solve a series of increasingly more complicated design challenges, eventually culminating in collaborative data analysis with other schools that have been sharing their designs. Design challenge modules incorporating a mixture of constructivism learning theory and cognitive load theory (Paas, Renkl, & Sweller, 2004) are supported by digital design and production technologies that enable students to participate in authentic creation via rapid prototyping. The primary emphasis of design challenges is on conceptual connections that leverage the students’ mathematical concepts in order to develop solutions to real-world problems, beginning with *Module 1: Introduction to Design* wherein students create simple designs, such as a trophy, using mathematics and evaluate using analysis, and students analyze the history of previous efforts to integrate STEM with the arts, developing an understanding of our opportunities for current and future STEAM initiatives, and ending with *Module 6: Design-themed Video Production* wherein students develop and produce a video demonstrating mathematical learning via audio and visual content about the design products and modules.

To support the scalability of the interdisciplinary STEAM instructional model, we are currently developing a system to make STEAM curricular materials and resources available through an online virtual-hub where students and educators can interact and co-create with artists, musicians, engineers, scientists, and mathematicians in a collaborative digital environment. The assessment instrumentation portion of this online system, branded as Adaptive Mathematics Aptitude-attitude Partner (AMAP), will measure the following five areas: conceptual understanding, procedural fluency, strategic competence, adaptive reasoning, and productive disposition (NRC, 2001) that have been grouped under three strands of: (a) concepts and procedures, (b) mathematical processes, and (c) productive dispositions. AMAP will also measure three strands for teachers: pedagogical content knowledge, proficiency at contextualizing mathematics pedagogy, and teaching style. With a combination of items assessing achievement and attitude, this instrument will be both adaptive and diagnostic. The assessment interface will be designed so that all of the assessment modules and results are entered into a website, and the teachers are given each student’s individual feedback to assist them in identifying what each one is understanding or struggling with.

*Summary of Discussion*

This discussion focused on the realization of engaging and meaningful STEAM education that is both scalable and assessable. For 2014 and beyond, the U.S. Department of Education will allocate $75 million per year to a new grant program "Effective Teaching and Learning for a Well-Rounded Education" (ETL-WE). This new program is a consolidation of eight previous funds that included the "Arts in Education Model Development and Dissemination" (AEMD) and seven other content specific funds such as those in foreign languages, civics, history, geography, and economics. In keeping with this shift in distribution of research funding, this discussion has focused on the integration of mathematics pedagogy into meaningful real-world contextualized activities involving creative projects that incorporate design and the arts, which have potential to help close the achievement and career gap in STEM. With a driving objective to generate heightened awareness and interest in STEM fields through these subjects’ natural intersection with the arts, we recognize the importance of not simply developing entertaining interactive experiences connected to the arts, but rather the necessity of doing so in ways that advance higher-order thinking through innovative mathematics learning experiences. The primary goal of this discussion was to foster teacher change towards an interdisciplinary pedagogical approach, with the convergence of three specific educational technologies serving as the foundation that make such pedagogy realizable and scalable. Digital multimedia will help teachers provide students with accessible and sustainable experiences with all manners of persons and events. Design tools will help students transition from abstractly interacting with STEAM content to physically creating products that ground ambiguous concepts in concrete experiences. Computer-based adaptive evaluations will enable students to move at their own individual pace, and will relieve teachers from being overwhelmed by grading and instead will allow them to spend more time focusing on pedagogy and customizing instruction for their diverse students. The combination of digital multimedia, design tools, and adaptive evaluation provides the supports needed for successful implementations of interdisciplinary STEAM pedagogy.

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